Understanding pore size relation in cellulose-derived, nitrogen-doped, hydrothermal carbons for improved supercapacitor performance

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Abstract

This study introduces an eco-friendly approach for synthesising cellulose-derived activated carbons, using hydrothermal carbonisation (HTC) followed by high-temperature pyrolysis. This novel method proves more carbon-efficient than the traditional carbonisation and activation processes. Moreover, we incorporate albumin as a sustainable nitrogen source in the preparation phase, with a view to enhancing the properties of the resulting carbons. We examine the morphological and textural characteristics of the carbons produced using scanning electron microscopy (SEM) and nitrogen sorption analysis. The chemical structure of the activated carbons was characterised using elemental microanalysis, Energy-Dispersive X-ray Spectroscopy (EDX), and X-ray Photoelectron Spectroscopy (XPS). The electrochemical evaluation was conducted in a symmetrical Swagelok cell, with a 2M H_2SO_4 aqueous solution electrolyte. The carbons obtained exhibited remarkable electrochemical performance, achieving capacitance values exceeding 275 F/g and power densities approaching 3000 W/kg. Crucially, we discovered a significant correlation between enhanced material capacitance and the presence of pores of around 4.3Å, the approximate diameter of the sulfate ion (SO_4^{2-}). This work highlights the significance of pore geometry in the electrochemical behaviour of the electrodes, advancing our understanding of the relationship between material structure and performance, and provides insight for the further development of sustainable high-performance materials for energy storage applications.

Supplementary material

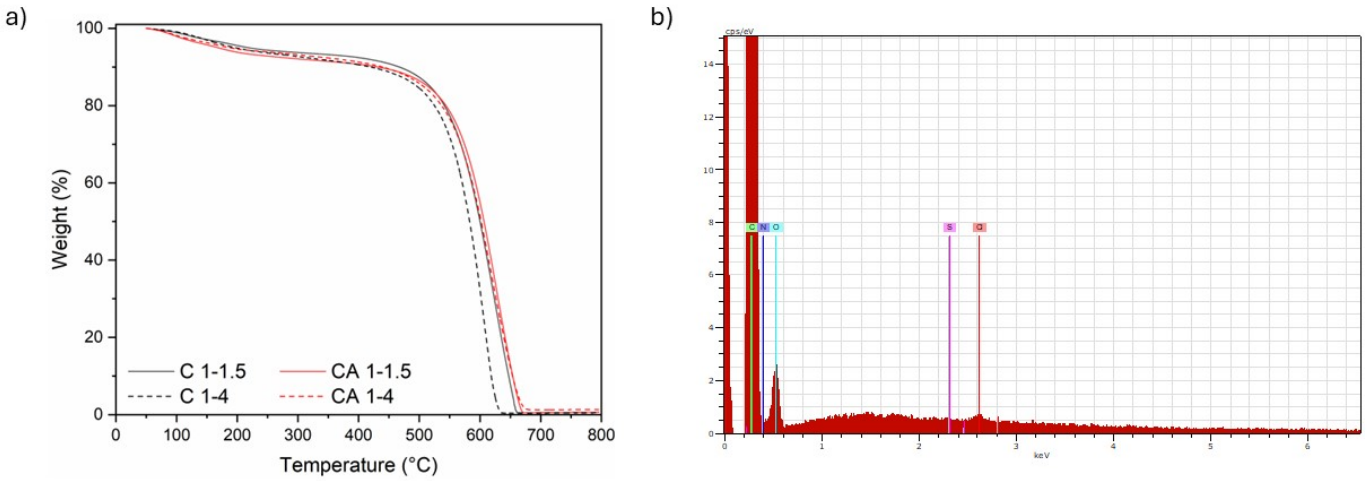

Figure S1:a) Thermogravimetric analysis of the final carbons; b) EDX spectra of the C 1-4 sample.

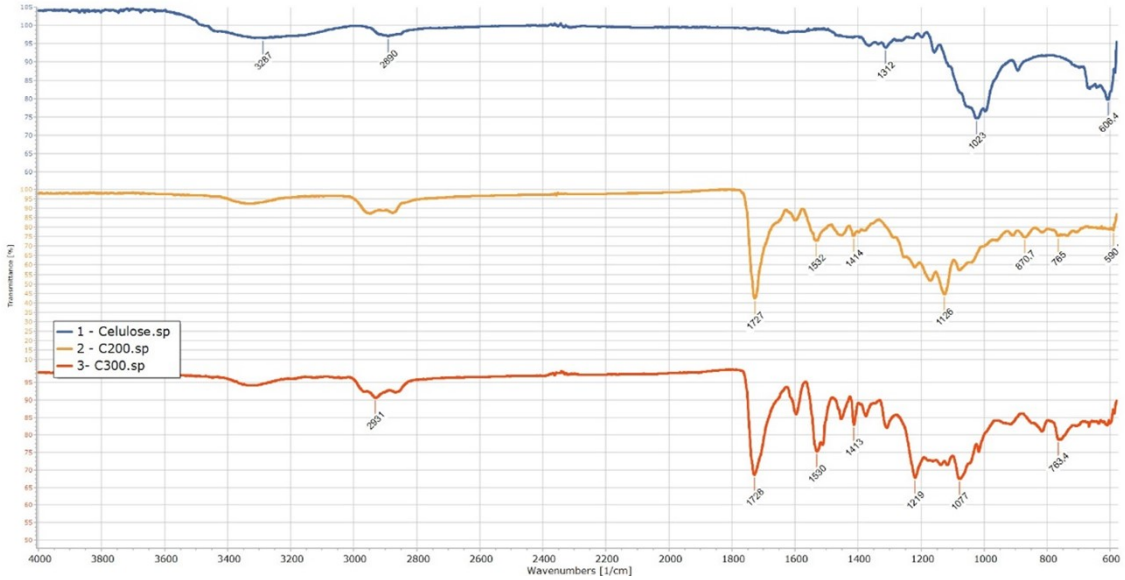

Figure S2:FTIR spectra of pristine cellulose, HTC treated cellulose (C200) and pre-heated, HTC-treated cellulose (C300)

Table S1: EDX results and comparison with elemental microanalysis (800ºC)

Sample	EDX			Elemental microanalysis		
	%C	%N	%O	%C	%N	%O
C 1-1.5	83.3	7.0	9.6	83.7	0.1	15.0
CA 1-1.5	83.0	7.3	9.7	83.0	1.1	14.4
C 1-4	86.3	5.0	8.5	82.7	0.2	16.1
CA 1-4	83.8	6.8	9.2	80.8	1.2	16.5

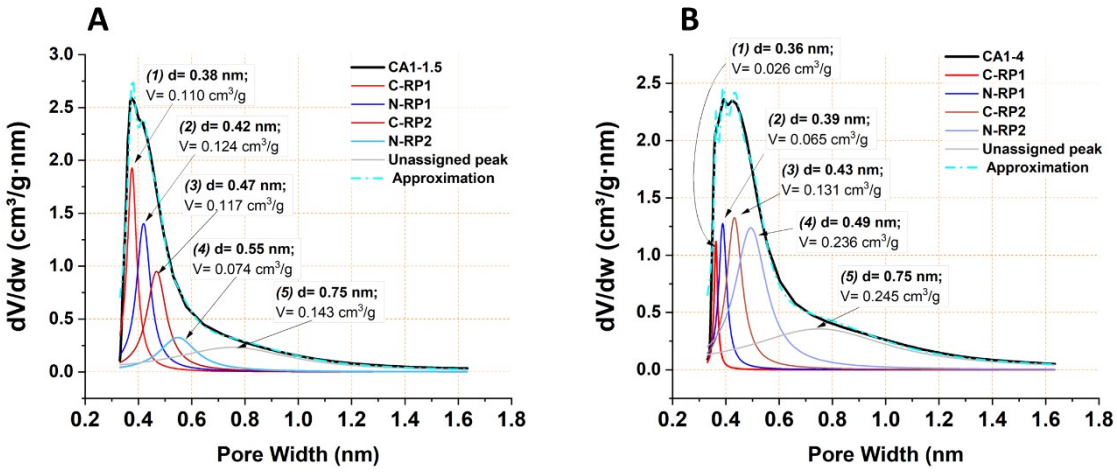

Figure S3: Lorentz deconvolution analysis of Horvath-Kawazoe pore size distribution of ACs derived from nitrogen-doped cellulose activated with different cellulose to KOH ratios: A) 1:1.5 and B) 1:4.

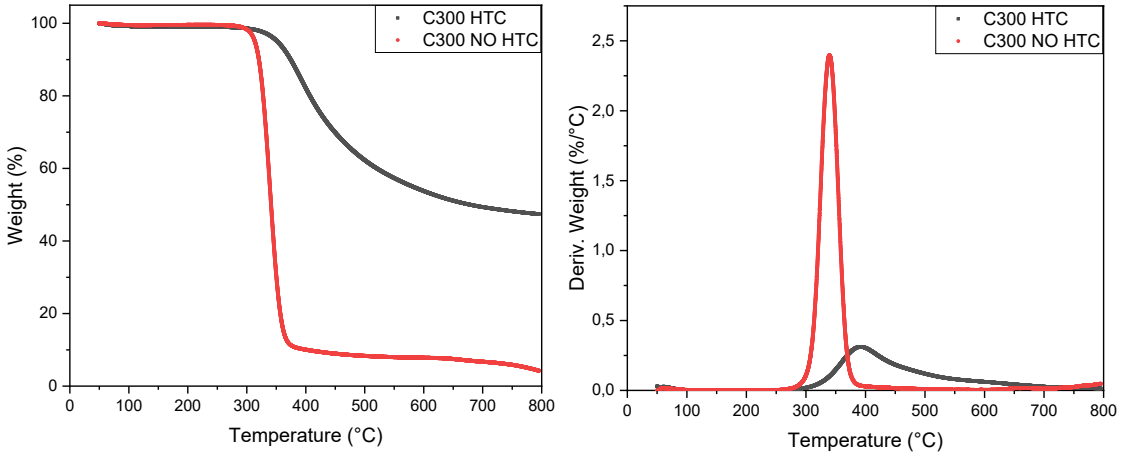

Figure S4:TGA and DTG for samples prepared at 300ºC with (black) and without (red) previous HTC.